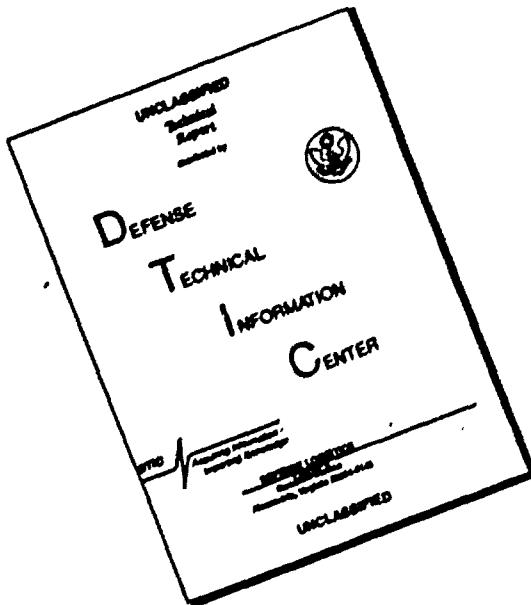


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COMPARISON OF SEAM TYPES

by

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Protective Sciences Division

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ABSTRACT

This study compares alternative seams with the double-lapped seam made in typical Canadian Forces fabrics in order to determine if a seam, other than the double-lapped seam, would be equally serviceable. An acceptable level of seam efficiency had been arbitrarily set at 80% by researchers in the fifties, and was used here. The double-lapped seam attained at least this level in all three fabrics used. Only one of the four alternative seam types evaluated in only one of the fabrics used reached this level. It was recommended that the criterion of 80% seam efficiency be revalidated because of the progress made since the fifties in the technology of sewing threads, seams and fabrics to make them all stronger and more durable.

RÉSUMÉ

Dans cette étude, les auteurs comparent différentes coutures à la double couture double rabattue effectuée sur les tissus qu'utilisent les Forces canadiennes dans la confection de leurs uniformes, afin de déterminer si une autre couture que celle précitée serait tout aussi résistante. Pendant les années 50, un groupe de chercheurs avaient établi, de façon arbitraire, à 80 p. cent le degré d'efficacité de la couture, pourcentage repris par les auteurs dans le cadre de leur recherche. Effectuée sur les trois genres de tissus utilisés, la double couture double rabattue respectait cette norme. Des quatre autres coutures mises à l'essai, seulement une d'entre elles atteignait cette norme et ce, exécutée sur un seul des tissus utilisés. Il a donc été recommandé de modifier la norme d'efficacité de 80 p. cent compte tenu des progrès réalisés depuis les années 50 dans le domaine des fils à coudre, des coutures et des tissus, lesquels sont tous beaucoup plus résistants et durables qu'à cette époque.

INTRODUCTION

The purpose of this study is to compare alternative seams with the double-lapped seam made in typical Canadian Forces fabrics in order to determine if a seam, other than the double-lapped seam, would be equally serviceable. The reason for this study is that many Canadian clothing manufacturers do not have the specialized equipment or high-trained personnel to construct the double-lapped seam which is used extensively for load-bearing seams in CF operational and protective clothing, and so are unable to bid on contracts for these items. The safety stitch and the seam-and-serge, with or without topstitching, may be constructed using relatively common sewing machines and personnel already trained in their operation. Any of the alternative seams found to have properties similar to the double-lapped seam could be used as a substitute and more clothing manufacturers in Canada could bid on DND clothing and equipment contracts.

REVIEW OF LITERATURE

A.P. Worthington has written an excellent and comprehensive review 'Stitches and Seams, a survey of the technical literature 1950-1979' (1). Unless otherwise indicated, the following literature review is taken from Worthington's survey rather than from the original papers, many of which are quite old and obscure. Dated references throughout the text refer to material drawn from reference (1).

The calculation of 'Seam Efficiency' allows for the comparison of stitch and seam types and of the same seam in different fabrics. It is defined as the seam breaking load divided by the fabric breaking load, expressed as a percentage. It is influenced by the strength of the sewing thread, type of seam and stitch, the number of stitches per unit length of seam and needle damage (for large or blunt needles). Seam Efficiency has been found to increase with stitch frequency to a limit and then falls due to needle damage.

In a study of cotton fabrics, drawn from general stock of the US Quartermaster Stores, Frederick (1952) recommended a minimum seam efficiency

of 80%, taking into consideration the intended use of the items made from these fabrics.

Workers (2) at the Shirley Institute (1939) studied the relative strengths of seams made in cotton drill cloth. Their results are adapted and given in Figure 1. It can be seen that the weakest seam is the plain seam (SSa-1) and that adding a second row of stitching in the seam allowance (SSa-2) does not improve the seam strength. However, it was later found that by placing the second row of stitching 0.8 mm (1/32 in) from the first rather than 6 mm (1/4 in), there was a noticeable increase in seam strength. The strongest seam was LSa-2, followed by the double-lap seam, LSas-2. The seam-overcast-topstitch seam was not included in their study, but a similar type of seam (LSr-2) was stronger than the plain seam, but considerably weaker than the lap seam (LSaS-2). Work by Burtonwood and Chamberlain (3) confirm this Shirley Institute study. They found that seam efficiency can increase to over 90% if two or more rows of stitching are used as in the manner of the strongest Shirley Institute seam (LSa-2).

In another study, Burtonwood and Chamberlain (1967) found that as the seam allowance is increased in width, the mean seam opening load increases, or, the greater the seam allowance, the more load is required to make the seam slip to the same extent. They found that seam slippage varies with the fabric and its inter-yarn friction.

Burtonwood and Chamberlain (1967) compared the relative strengths of stitch types. They found that chainstitch seams are slightly stronger than lockstitch seams and suggested that less needle damage to the thread occurs in forming this chainstitch. Singer (1952) also found this, but felt that the lockstitch was a more durable stitch than the chainstitch as it did not unravel as readily and was set deeper into the fabric to reduce abrasion and snagging of the thread.

In a study of stretch fabric seams, Bernier (1965) comments that the lap seam has four layers of fabric in it and so four times the stress in stretching the adjacent fabric, resulting in seam pucker and yarn severance since the movement of the yarns in the fabric is so severely restricted.

METHOD

MATERIALS USED

Three fabrics used extensively in the Canadian Forces for combat clothing, coveralls and flying suits were selected for study. They are a lightweight and a heavyweight plain weave nylon/cotton twist and a nylon 2/1 twill. The thread was selected to match each fabric, the same kind of thread

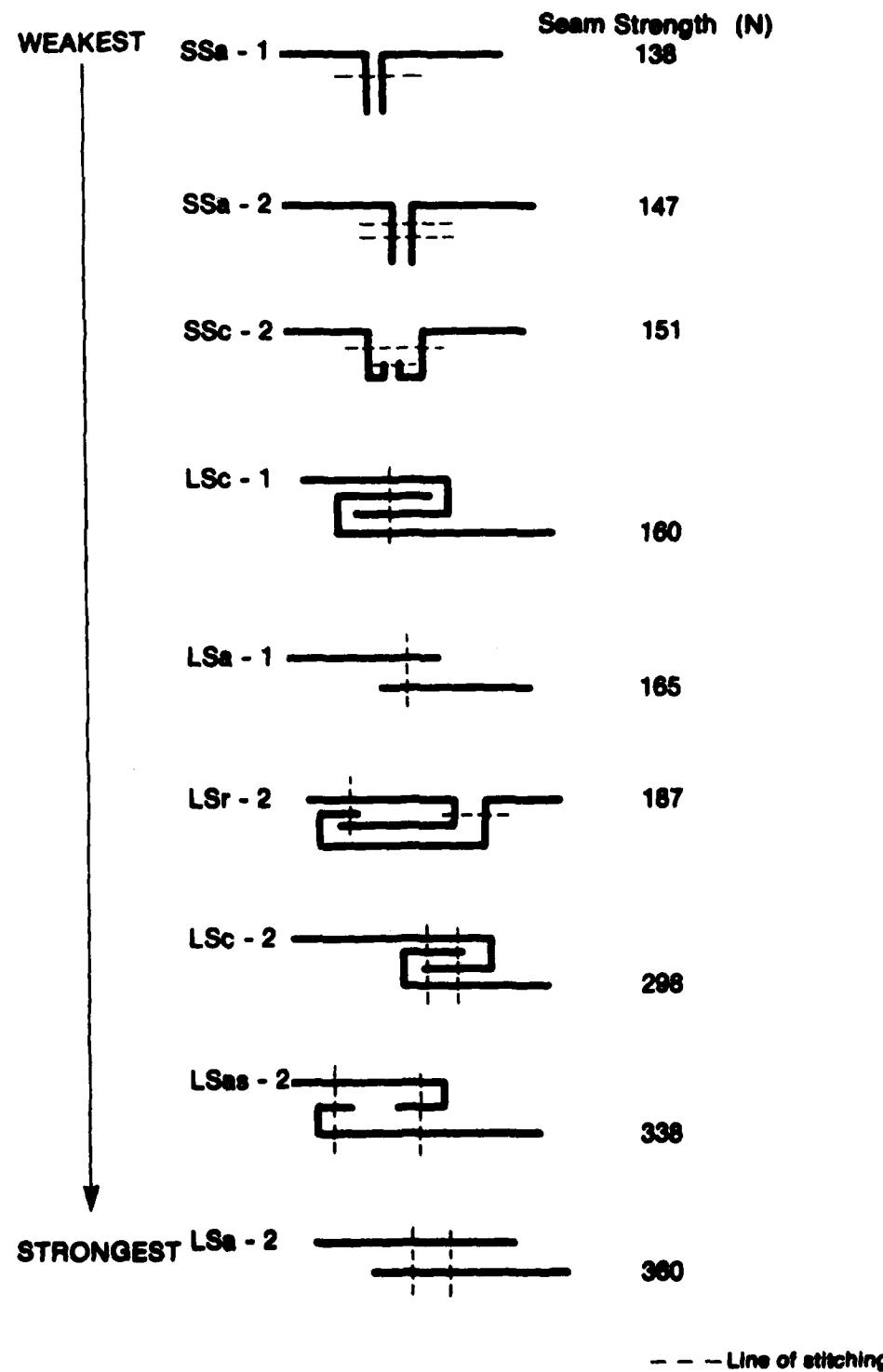


Figure 1: Relative Strengths of Seams (2).

being used for all types of seams made in that fabric. "Canadian Sewing Supply Ltd. Polycore 50" was used in the lightweight nylon/cotton twist fabric, "J&P Coats Koban N233", in the heavyweight nylon/cotton twist fabric and "Coats Koban N526" in the twill fabric. Coats Drima-TN208 was used for the serging.

SEAM DESCRIPTIONS

Five types of seams were made in the three fabrics, except for the safety seam in the warp of the light fabric, and for the safety and topstitch in the weft of the twill fabric. These seams were originally omitted in error, and then not included since the seam efficiency of the safety seam in the weft of the light fabric and the safety and topstitch in the warp of the twill fabric were below 80%.

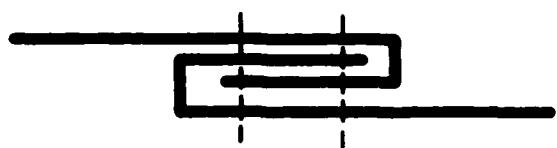
The double-lap seam and stitch type is shown in Figure 2, the safety seam in Figure 3a, the safety and topstitch seam in Figure 3b, the stitch and serge seam in Figure 4a and the stitch and serge and topstitch seam in Figure 4b.

The double-lap seam is made in one operation. The safety seam (chainstitch and overcasting) is also made in one operation, with the topstitching of this seam requiring a second pass through the lockstitch sewing machine. The stitch and serge seam requires one pass to make the lockstitch seam and a second through a serging machine to serge the edges of the seam. A third pass through the lockstitch machine is needed for the topstitching.

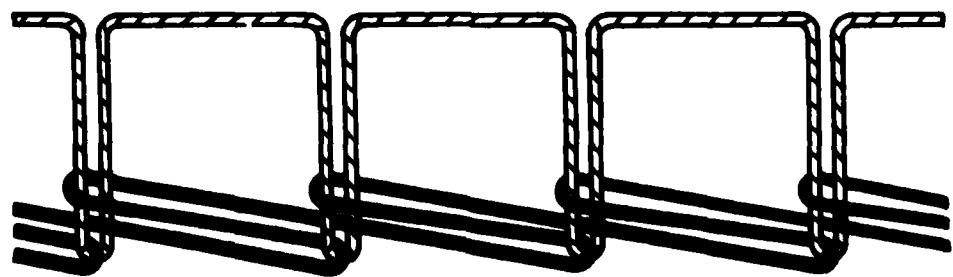
SEWING MACHINES USED

A Singer 261-42 sewing machine was used for the double lap seam, with a needle for the heavy fabric and a #16 needle for the light fabric and the twill. The Singer 251-2 was used for all the lockstitches, with a #16 needle for the heavy fabric and a #14 for the light fabric and twill. A Singer 460K75 was used for the serging and a Singer 991E3 for the safety seam. These sewing machines and needle sizes were selected because they are representative of what is normally used with these fabrics in industry.

Because of the stop-go method of sewing the seams, it was not possible to measure the sewing machine speed during seam construction.

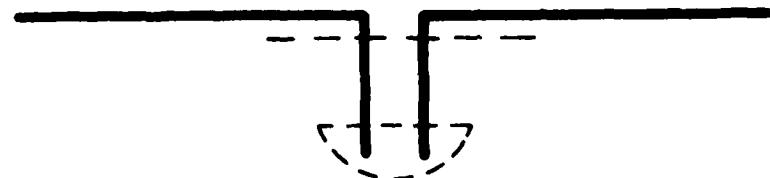


Seam Type
LSc-2



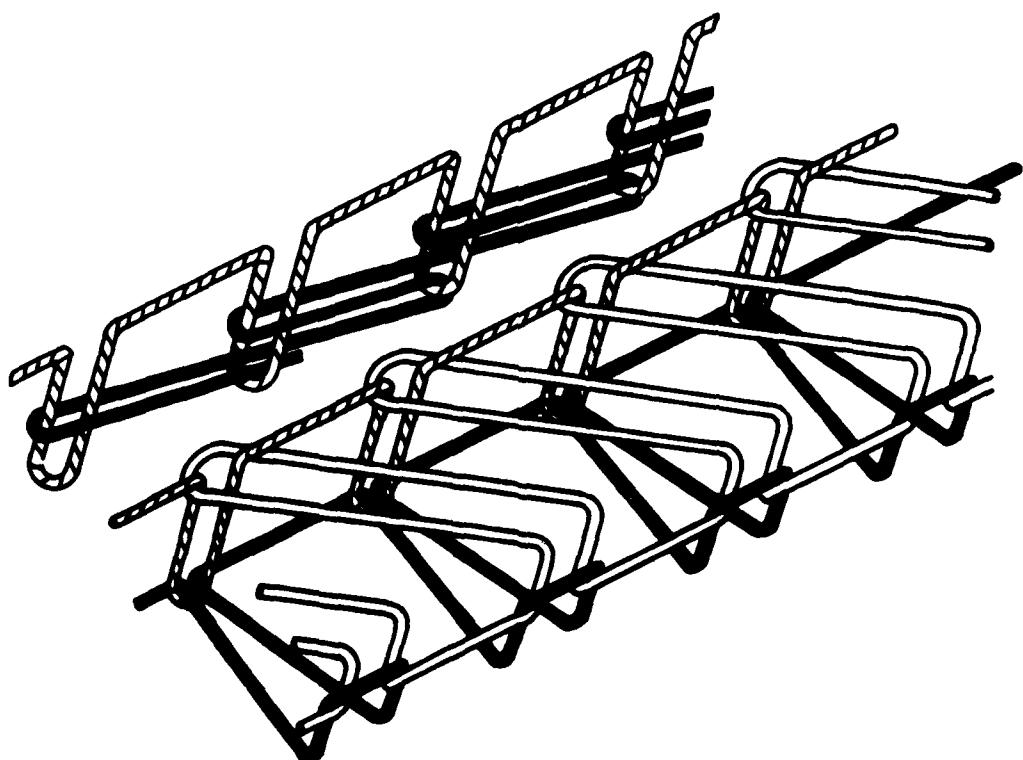
Stitch Type - Double Lock Chainstitch (401)

Figure 2: Double Lap Seam 401-LSc-2.



Seam Type

EFd-1-SSa-1



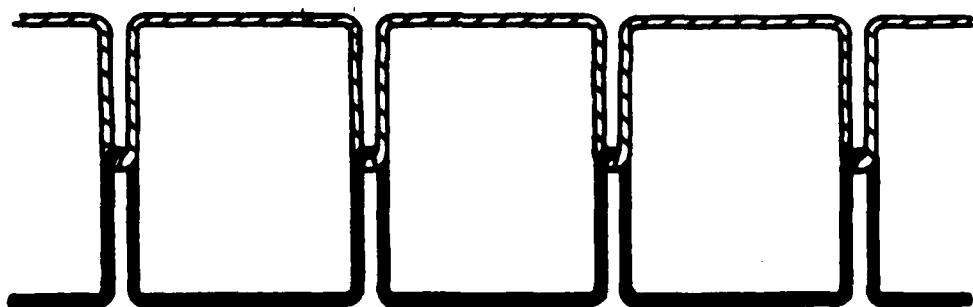
Stitch Type - Safety - Combined Chainstitch (401) and Overcase (504)

Figure 3a: Safety Seam (504.401)-EFd-1-SSa-1.



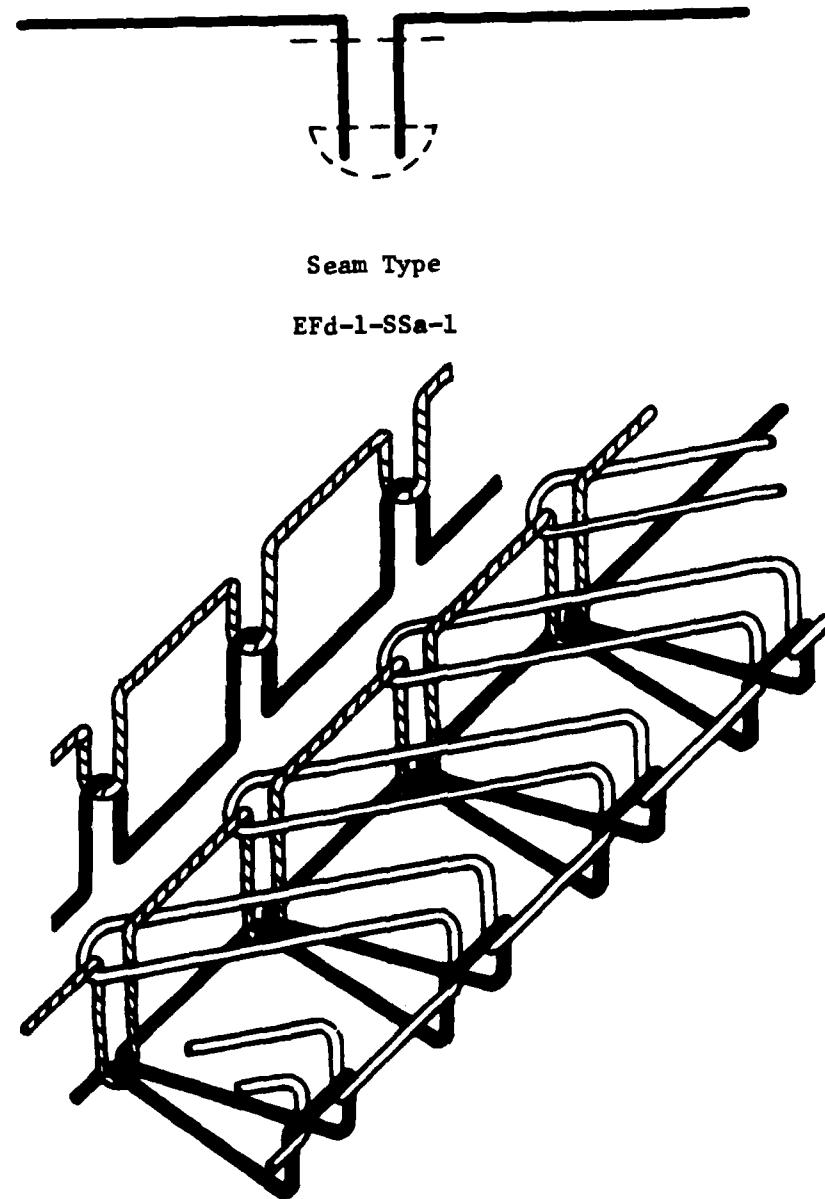
Seam Type

EFd-1-LSg-2



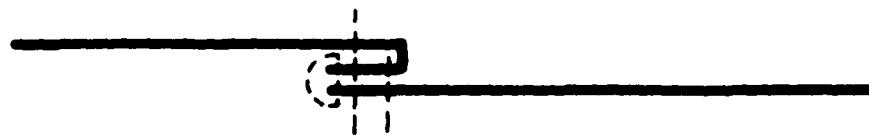
Stitch Type - As Figure 3a Plus Topstitching of Lockstitch (301)

Figure 3b: Safety and Topstitch Seam
(501.401). 301-EFd-1-LSg-2.



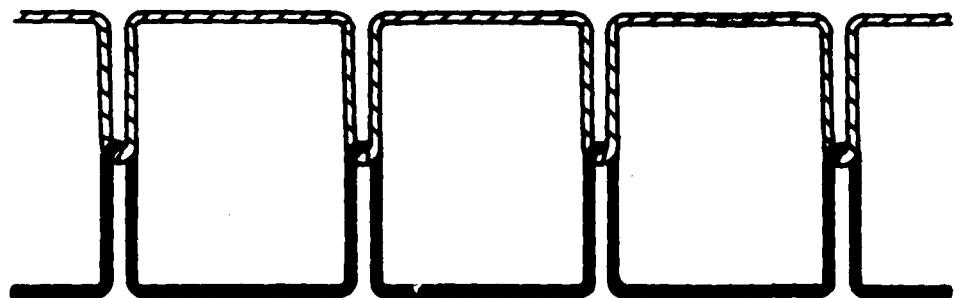
Stitch Type - Combined Lockstitch (301) and Overlock (504)

Figure 4a: Stitch and Serge Seam
504.301-EFd-1-SSa-1.



Seam Type

EFd-1-LSg-2



Stitch Type - As Figure 4a Plus Topstitching of Lockstitch (301)

Figure 4b: Stitch-and-Serge and Topstitch Seam
504.301.301-EFd-1-LSg-2.

DETERMINATION OF FABRIC AND SEAM PROPERTIES

Seam specimens were prepared in accordance to ASTM D 1683-81 "Standard Test Method for Failure in Sewn Seams of Woven Fabrics" and fabric specimens in accordance with ASTM D 1682-64 (Reapproved 1975) "Standard Methods of Test for Breaking Load and Elongation of Textile Fabrics". Specimens were prepared in both the warp and weft directions, the lengths of seams ranging from 64 cm to 174 cm. The specimens designated "warp direction" have the seam running parallel to the weft. The seams were made by experienced sewing machine operators with well-maintained equipment at the Directorate of Clothing General Equipment and Maintenance.

Several measurements were made on the seamed strips. The percent seam shrinkage was calculated, based on the length of the strip at the fabric edge and along the seam. The number of stitches per 25 mm at 5 locations along the seam were counted. The number of stitches per 25 mm were counted for the overcasting when the seam was not topstitched, and the number of stitches per 25 mm of topstitching counted where it occurred, and that of the overcasting not counted. This was because it was extremely difficult to count stitches in the overcasting when the seam had been topstitched through the overcasting. It was assumed that the stitch density of the overcasting in the topstitched seams would be the same as that in the un-topstitched seams as both seam types were made on the same sewing machines by the same operators, using nominally the same stitch density for each fabric.

The stitch gauge, i.e. the distance between two rows of stitching, the seam and the overcasting or the seam and the topstitching, was measured.

The seams were rated in appearance using the AATCC rating photos given in AATCC Test Method 88B-1973 "Appearance of Seams in Wash-and-Wear Items After Home Laundering".

The fabric and seam samples were broken on a Instron Model 1102 according to ASTM D 1682-64 and ASTM D 1683-81, mentioned at the beginning of this section.

RESULTS AND DISCUSSION

The pertinent properties of the fabrics are given in Table 1, of the threads in Table 2, and the results of the measurements on the seams are given in Tables 3 to 5. If one accepts Frederick's recommendation that a seam should have a minimum seam efficiency of 80%, then the double lap seam in all three fabrics, in both the warp and weft directions, is an acceptably strong seam. The safety and topstitch seam in the heavy fabric has a breaking load equivalent to that of the double lap seam, within experimental error, thus making it an acceptable, serviceable seam in that fabric. Although the stitch-and-serge and topstitch in the weft direction of the twill has a seam efficiency well over 80%, the seam is unacceptable since the efficiency is only 61% in the warp direction. Seams in clothing run in both the warp and weft directions, and thus serviceable seams are required in both directions.

The fact that the double lap seam is consistently the strongest seam, and the stitch-and-serge the weakest, agrees with the results of the workers at Shirley Institute (1939).

The seam efficiencies in the warp and weft directions in the light and heavy fabrics are quite similar in magnitude, whereas the seam efficiencies in the warp direction of the twill are always considerably lower than in the weft direction except for the double lap seam where they are about the same. This is probably because the light and heavy fabrics have more or less a balanced count (same number of threads per cm in the warp and weft) and a balanced yarn structure, whereas the twill has an unbalanced count, a continuous filament warp and a staple fibre weft which encourages fraying. This would allow the fabric threads to slip out of the seam readily, or vice versa, except for the double lap seam where the fabric edges are encased in the seam. The safety seam, topstitched or not, in the twill, failed due to seam slippage in all cases. The stitch-and-serge main lockstitch seam in the twill failed mainly from the thread breaking. This could be explained by an observation of Burtonwood and Chamberlain (1967), namely, that the wider the seam allowance or gauge, the more load is required to break the seam. In the case of the stitch-and-serge this load is sufficient to break the sewing thread. The safety seam has a narrower gauge than the stitch-and-serge seam, so the thread in the seam can easily slip through this narrow seam allowance without the thread breaking.

For the heavy and light fabrics, the safety seam with its chain-stitch was generally stronger than the stitch-and-serge with its lockstitch, topstitched with a lockstitch or not. This again agrees with the results of Burtonwood and Chamberlain (1967).

TABLE 1
Pertinent Fabric Properties

	Fabric					
	Light		Heavy		Twill	
Mass g/m	154		280		220	
	Warp	Weft	Warp	Weft	Warp	Weft
Count (threads per cm)	24	20	17	16	46	25
Breaking Load (N)	636	546	1029	991	530	383
cv	1	3	3	3	2	3
% Elongation at Break	28	33	35	35	28	8.6
cv	4	3	2	3	3	3

cv = coefficient of variation (%).

TABLE 2
Pertinent Thread Properties

	Polycore 50	Koban N233	Koban N526	Drima-T N208
Fibre Content	Corespun 65% polyester 35% rayon	Continuous filament polyester	Corespun 65% polyester 35% cotton	Spun polyester
Construction	2 ply Z twist	2 ply Z twist	2 ply Z twist	3 ply Z twist
Tex	51	53	53	36
Breaking Load* (N)				
\bar{x}	18.0	14.9	17.5	9.9
σ	0.4	0.8	0.4	1.7
cv	2	5	2	17
% Elongation				
\bar{x}	21	22.5	28	17
σ	0.6	0.9	1.1	2.3
cv	3	4	4	14

* Measured according to CAN 2-4.2-1977, Method 9.4 - 1977
Method of Test for Breaking Strength of Yarns - Single Strand
Method (Constant-time-to-break Principle).

σ - standard deviation.

cv - coefficient of variation.

TABLE 3
Performance Properties of Seams in Light Fabric

Double Tap	Safety			Same Type Safety and Topstitch			Stitch-and-Serge and Topstitch			Stitch-and-Serge and Topstitch	
	Warp	Weft	Warp	Warp	Weft	Warp	Warp	Weft	Warp	Weft	
Breaking Load (N)	545	477	No	368	422	275	200	191	407	375	
2 Seam Efficiency	86	87	Sample	67	66	50	31	35	59	69	
CV	10	5		4	8	4	6	4	8	14	
2 Elongation at Break	29	37		36	30	31	22	20	27	33	
2 of Fabric Elongation	86	112		109	107	94	79	61	96	100	
CV	3	3		3	3	3	6	4	5	8	
Cost of Break											
Seam											
Thread-5	Fabric-4			Thread-2	Thread-5	Slippage-3	Thread-5	Thread-5	Thread-5	Thread-5	
Thread-5	Thread-1			Slippage-3	Slippage-5	Slippage-5	Slippage-5	Slippage-5	Slippage-5	Slippage-5	
Topstitch				Slippage-5	Slippage-5	Slippage-5	Slippage-5	Slippage-5	Slippage-5	Slippage-5	
Overcast											
Seam Shrinkage (2)	1.3	2.3	0.8	1.2	1.1	2.0	0.4	0.4	0.6	1.5	
Minimum Differential Pond (mm)	3 to 23	1 to 9	0 to 5	0	0	12	11	11	12	0	
Seams in Seams per 25 mm											
Seam	10	10-11		16-15	16	16	8	8	8	8	
Topstitch	10	10-11		10	10	10	9	9	11	10	
Overcasting				3-4	5	6			6	6	
CV (mm)	7	7		3	1	1	1	1	1	2	
Number of Seams	3	3		Good - slight pucker	Excellent	Very Good	Excellent	Very Good	Very Good	Very Good	
Visual Appearance				4.5	5	4	5	5	4.5	4	
ASTC Rating	4	3									

Good - slight
pucker
4.5

Excellent
Very Good
4

Very Good
4

TABLE 4
Pertinent Properties of Seams in Heavy Fabric

Double Lap WST	Welt	Safety		Safety and Topstitch		Stitch-and-Sew		Stitch-and-Sew and Topstitch Welt	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Breaking Load (N)	638	792	723	653	615	650	525	319	593
% Seam Efficiency	61	80	70	66	79	86	31	32	59
cv	6	5	5	5	6	13	5	5	3
% Elongation at Break	35	31	35	36	39	35	27	22	30
% of Fabric Elongation	100	69	100	103	111	100	77	63	83
cv	5	0	4	6	5	8	9	4	3
Cost of Break Seam	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5
Topstitch	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5	Thread-5
Overcast	Thread-5	Slipper-2	Thread-2	Slipper-4	Thread-2	Thread-3	Slipper-2	Slipper-2	Slipper-2
Seam Shrinkage (%)	0.5	1.0	0	1.3	0.6	1.0	1.1	0.7	0.4
Maximum Differential Feed (mm)	6-10	9-10	9	0	5	7	6	3	0
Seitches in Seam per 25 mm	Seam Topstitch Overcast	11 10-11 10-11	11 14 14	14 14 14	9 14 14	9 14 14	9 9 9	9 9 9	10 10 10
Gage (mm)	7	6.5-7	3	3	5	5	5	6-6.5	8.5
Number of Seams	2	1	1	1	1	2	1	2	1
Visual Appearance	Very Good	Good - slight pucker	Very Good	Excellent	Excellent	Very Good	Very Good	Very Good	Very Good
AATCC Rating	5	4	3	4	4.5	4.5	5	5	5

TABLE 5
Performance Properties of Seams in Twill Fabric

Sample No.	Wt.	Seams		Seams		Seams		Seams	
		Topstitch	Naft	Topstitch	Naft	Topstitch	Naft	Topstitch	Naft
Breaking Load (N)	356	493	144	269	43	No Sample	206	207	325
2. Seam Efficiency	100	100	27	75	18	30	34	61	398
CV	3	5	49	3	50	4	4	8	104
2. Elongation at Break	36	36	21	21	9	22	13	15	6
2. of Fabric Tension Loss	121	126	75	244	32	79	46	174	15
CV	2	5	35	3	22	3	3	0	3
Count of Break Seams	Wardle-5	Wardle-2	Slippage-1	Slippage-5	Slippage-5	Thread-5	Thread-4	Slippage-3	Slippage-3
Wardle-5	Wardle-5	Wardle-5	Slippage-1	Slippage-5	Slippage-5	Slippage-5	Slippage-4	Slippage-4	Slippage-3
Slippage-5	Wardle-5	Slippage-5	Slippage-5	Slippage-5	Slippage-5	Slippage-2	Slippage-4	Slippage-4	Slippage-3
Overall	Wardle-5	Wardle-5	Slippage-5	Slippage-5	Slippage-5	Slippage-3	Slippage-3	Slippage-3	Slippage-3
Seam Strength (N)	0.6	2.4	0.4	2.8	0.5	0.3	2.2	1.5	2.4
Minimum Difference (N)	2-3	6-3	7	5	5	2	6-14	0.9	13
Naft (cm)									
Stitching in Seam per 25 cm									
Seams	10	11	10	15	10	8	9	8	10
Topstitch	10	11	10	14	14	9	9	15	10
Oversewing						5	4-5	4	6
Group	7	7	2	3	1	1	2	1	7
Number of Seams	2	2	1	1	1	1	1	1	1
Visual Appearance	Very Good	Poor - poor	Very Good	Excellent	Good - good	Poor - poor	Poor - poor	Poor - poor	Poor - poor
Average Rating	4	3	5	4	4	4	4	4	4

The extension of the fabric in the specimen, the slippage of the thread in the seam and the extension of the sewing thread itself can all contribute to how much a seam elongates before it breaks.

In general for the light and heavy fabrics, the percent elongation at break of the seams is of the same magnitude as that of the fabric, except for the stitch-and-serge seams which have a lower percent elongation at break than the others. This is probably due to the fact that a lockstitch has less thread in it than a chainstitch, and so it can extend less than a chain-stitch before it breaks.

The topstitched or dual row seams are quite rigid seams with the thread being "locked" into the fabric due to friction (the thread going through 3 to 4 layers of fabric). Since the thread cannot extend very much in the seam, it is the fabric extension which contributes most to the total elongation.

For the twill fabric, the percent elongation at break tends to vary with the breaking load: when the breaking load is high, the percent elongation at break is high and vice versa. As mentioned earlier, the twill fabric frays quite readily, more so in the weft direction than in the warp. As a consequence, it does not take much loading to allow the seam thread to slip through the fabric, giving rise to high extensions at break. For the lap seam, the fabric broke before the seam, and in the weft direction, three of the five specimens also had seam slippage as well as fabric breaks. This caused the weft to have a higher percent elongation at break than the warp. The safety seam topstitched, or not, had slippage in all cases and its percent elongation at break is directly related to the breaking load.

The measured seam shrinkage due to puckering was no more than 3% for any of the seams. However, in a 100 cm outer pant leg seam, this would give a 3 cm shrinkage which would probably be quite noticeable. With the twill, the seam shrinkage in the weft direction was always considerably greater than in the warp direction. This seam shrinkage or puckering would probably be due to structural jamming, since the count in the warp is almost twice what it is in the weft. No one seam type seemed any better or any worse than the others for seam shrinkage.

The measured seam shrinkage and the visual rating of the seams were done by two separate individuals and the physical and observed differences do not correlate particularly well, i.e. a seam with a relatively large seam shrinkage was not necessarily rated a poor seam. Thus it would appear that a seam could have some seam shrinkage and still appear to be visually acceptable.

CONCLUSIONS

If the criterion of a minimum of 80% seam efficiency is applied, then the safety and topstitch seam in the heavy weight nylon/cotton twist fabric is the only seam which could replace the double lap seam. No alternative seam was found strong enough to replace the double lap seam in the lightweight nylon/cotton fabrics or the nylon twill.

RECOMMENDATION

It is recommended that the criterion of 80% seam efficiency be revalidated because of the progress made since Frederick's work in 1952 in the technology of sewing threads, seams and fabrics to make them all stronger and more durable.

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12. SPONSORING ACTIVITY

13. ABSTRACT

This study compares alternative seams with the double-lapped seam made in typical Canadian Forces fabrics in order to determine if a seam, other than the double-lapped seam, would be equally serviceable. An acceptable level of seam efficiency had been arbitrarily set at 80% by researchers in the fifties, and was used here. The double-lapped seam attained at least this level in all three fabrics used. Only one of the four alternative seam types evaluated in only one of the fabrics used reached this level. It was recommended that the criterion of 80% seam efficiency be revalidated because of the progress made since the fifties in the technology of sewing threads, seams and fabrics to make them all stronger and more durable.

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